Computational Design and Fabrication of 3D Wire Bending Art

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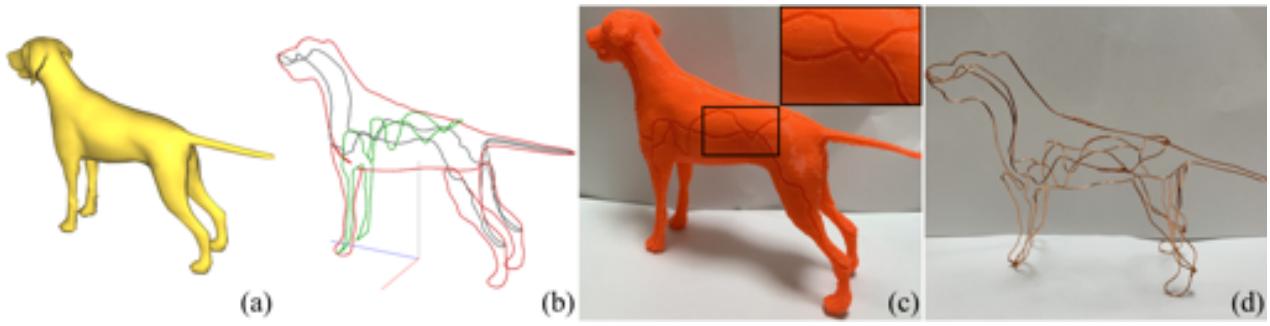

Figure 1: Given a 3D model (a), our system enables users to generate wire abstraction (b) and 3D printed support (c) to aid users bending wire into the sculpture (d).

ABSTRACT

Wire sculpture is a unique art form where an artist represents a 3D form using 1D wires. However, the design of novel wire sculpture is difficult and limited to talented experts. We introduce a computer-assisted framework for manually creating 3D wire bending art from given 3D models. Our method extracts a set of 3D contour-curves from several viewpoints as a target design of wire sculpture. Next, we generate several grooves on the 3D surface of the given model, and prints it with 3D printer as a 3D support. By directly fitting wires into the grooves and assembling, users can manually fabricate 3D wire bending art easily and quickly.

CCS CONCEPTS

• **Computing methodologies** → Graphics system and interface.

KEYWORDS

wire sculptures, 3D printing, geometry modeling

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1 INTRODUCTION

"I think best in wire." , said Alexander Calder, one of the famous sculptors of 20 century in America, who developed wire as a material for sculpting. Wire is a kind of pseudo one dimensional material that gives a sense of drawing in three dimensions. As an exceptional form of art, this break-through of wall in dimensions leaves blank for creativity and imagination to happen. Wire sculptures wildly take inspiration from animals, figures, household goods, daily objects and so on. Art styles also vary from artist to artist. The scales and materials have an influence on expressiveness of the sculptures. Due to all these and non mentioned variations, wire sculpture is usually done by artists and craftsmen depending on their great abstraction ability and crafting techniques. These are also the two main challenges for untrained people creating wire sculptures.

Several techniques that extract the curve paths from a single image (line drawing) have been shown to deliver feasible wire structures [Iarussi et al. 2015; Liu et al. 2017]. Although these approaches works well for certain users, it is not trivial for these techniques to generate 3D wire sculptures. Here, our goal is to abstract shape-featured wires from a 3D model and guide users bending the wire during the actual fabrication task.

The user firstly specifies several viewpoints (for example, front & side), and the system automatically extracts 3D curves of the input model from the user-specified viewpoints. After smoothing and optimization processes, we fabricate a 3D printed support with grooves on the surface. By bending and assembling wires with aid of the 3D printed support, users can fabricate wire arts of their own interest. The wires can be bent one by one to get the designed shape and assembled together. Figure 1 illustrates each step of our method obtaining 3D wire art from the 3D model.

Figure 2: Examples of 3D wire bending arts (Giraffe, Dinosaur, and Human Head) created by the proposed system. The input 3D models are shown in the left figure, and the middle and right figure show the 3D printings and final wire arts, respectively.

2 METHOD

2.1 Wire Abstraction

We apply Cipolla's method [1998] to extract the contour-curves of the input model from one viewpoint. Note that the extracted contour-curves are closed when the input is a closed manifold mesh. However, the single viewpoint-based result may lack distinctive characteristics of 3D model which can be easy observed from other viewpoints. We therefore select three viewpoints (i.e., front, side and top view) based on the Axis-Aligned minimum Bounding Box, and extract multiple-view 3D curves. These viewpoints appear to work well, but any other viewpoint could also be used with our framework. In addition, due to various shape of the mesh, we obtain a dozen of the contour-curves from one single mesh. Sorting by amount of segments and Laplacian smoothing are performed to obtain the balance between the concision and the expressiveness.

2.2 Fabrication with 3D Printed Support

The system extrudes tubes along the contour-curves on the 3D model and applies Constructive Solid Geometry (CSG) [Zhou et al. 2016] to subtract the tube models from the object mesh for designing the grooves on the 3D model.

Next, we print the 3D model with grooves using an FDM-based 3D printer. By using the printed model as bending support, wire bending process becomes fitting each wire into the groove on 3D printed support. However, there often appear the grooves intersections on the 3D model. In order to specify the exact path for each curve, the proposed system directly assigns different colors to curves respectively (see Fig 1(b)), and visualize it to user on the screen. In addition, during bending task, it might be difficult to

keep the bent parts inside the grooves due to the hardness of the wire material. In this project, we simply use tape to directly stick the wires in the groove. The inset figure shows how user bends the wire on the 3D printed support.

For assembling wires, we must consider how to connect 1) the ends of one single wire, and 2) the intersections of two wires. After comparing several methods for connection, we choose tying up with ultra thin wire. It's efficient enough as well as feasible for both ends and intersection connections. If the users chooses zinc plating wire or soldering wire itself, soldering is an alternative.

3 RESULTS

Figure 1 shows the details of how the system works by each step. More wire sculptures are illustrated in Figure 2. Note that all the sculptures are made of copper, tied by ultra fine copper wire.

4 LIMITATIONS AND FUTURE WORK

This project is extremely user oriented while our user interface is trivial. It is vital to offer more freedom for user in this process especially the wire abstraction part. Changing viewpoint in real time, selecting preferable curves between a large amount of automatically generated ones or allowing user to drag the curves to favorable positions could be interesting ideas. The support works pretty well in aiding the fabrication. The grooves guarantee the expressiveness of each fabricated wire. On the other hand, 3D printing restricts the fabricable size of wire sculpture. To create wire sculptures of large size, users need to find larger 3D printer. We expect to offer flexible support for larger scale of design by widely available machine.

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